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Energy-efficient heating appliances:

Drivers of behavior change

Catarina Paisana Pires Costa das Neves

Dissertation presented as the partial requirement for obtaining a Master's degree in Information Management

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Drivers of behavior change

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Dissertation presented as the partial requirement for obtaining a Master's degree in Information Management, specialization in Knowledge Management and Business Intelligence

Advisor: Prof. Dr. Tiago André Gonçalves Félix de Oliveira

June 2021

DEDICATION

Aos meus pais, muito obrigada pelo apoio incondicional, por nunca duvidarem das minhas capacidades e, acima de tudo, por não me deixarem duvidar delas. À minha irmã, obrigada por estares sempre a meu lado, és a minha companheira desta jornada. Avós, tios e prima, obrigada por estarem sempre presentes. Primos, serão sempre o meu exemplo. Sem todos vós, nunca conseguiria estar onde estou. Ao João, obrigada por todo o carinho, apoio e paciência.

Aos meus amigos, obrigada por toda a amizade e por me apoiarem desde sempre, estejam longe ou perto.

ACKNOWLEDGEMENTS

To Professor Tiago Oliveira and Frederico Cruz Jesus, for the opportunity to work and learn with them. I am very thankful for all the support in this work, but specially for the availability, friendliness, and mainly for the confidence you placed in me in the last years. Without you, I would not be able to do what I am doing today.

To Nova Information Management School for providing me an education of excellence, and all the resources to develop this work. I am grateful for the day I came into this Institution and for everything I learned.

Also, this work was supported by the European Union's Horizon 2020 research and innovation program [grant agreement No 847049]. I would like to thank the HARP (Heating appliances retrofit planning) project consortium, consisting of *Agência para a Energia* (ADENE), *R2M Solution Spain SL* (R2M), *European Environmental Citizens Organization For Standardization* (ECOS), *University of Minho* (UMINHO), *ANIMA Federazione delle Associazioni Nazionali dell'Industria Meccanica Varia ed Affine* (ASSOTERMICA), *European Solar Thermal Industry Federation* (SHE/ESTIF), *Association of the European Heating Industry* (EHI), *Accademia Europea di Bolzano* (EURAC), *Agenzia Nazionale per le Nuove Tecnologie, L'energia e lo Sviluppo Economico Sostenibile* (ENEA), *Deutsche Energie-Agentur GMBH* (DENA), *Creara Consultores SL* (CREARA), *Uwe Trenkner* (TRENKNER), *Associação Portuguesa para a Defesa do Consumidor* (DECO), *Syndicat des industries thermiques, aérauliques et frigorifiques* (UNICLIMA), *Nova University of Lisbon* (NOVA IMS), *Energies et Avenir -Association des professionnels pour le chauffage durable* (EA), *Organisation of Consumers and Users* (OCU) and *Energies 2050* (ENERGIES2050), for their support in the data collection for the qualitative study and the validation and dissemination of the questionnaires in all five countries.

From this dissertation, a scientific article was published in Applied Energy Journal, with the title "Drivers of consumers' change to an energy-efficient heating appliance (EEHA) in households: Evidence from five European countries".

ABSTRACT

Our research analyses the drivers for consumers to change to energy-efficient heating appliances. The residential sector is a significant contributor to global energy consumption, and therefore for the increasing climate changes. Thus, there is a need to extend the knowledge on the topic of energy efficiency and better understand the consumer behaviour. To achieve this, our work test six relevant contexts (triggers, barriers, engagement, house characteristics, co-benefits, and communication channels) to predict behavior change. The model was tested based on a sample collected in five European countries, using structural equation modelling technique. We conclude that co-benefits and organizational and web media communication channels significantly affect the behaviour intention to change. Moreover, our results emphasize the importance of consumer engagement in energy topic. These findings are extremely relevant for both energy and governmental organizations towards increasing households' energy efficiency.

KEYWORDS

Efficient energy; Energy efficient heating appliance; Consumer behavior; Structural equation modeling

RESUMO

A nossa pesquisa analisa os fatores que levam os consumidores a mudar para aparelhos de aquecimento com eficiência energética. O setor residencial contribui significativamente para o consumo global de energia e portanto para as crescentes alterações climáticas. Assim sendo, é necessário alargar o conhecimento sobre o tema da eficiência energética e compreender melhor o comportamento do consumidor. Desta forma, este trabalho testa seis contextos relevantes (motivadores, barreiras, envolvimento, características da casa, co-benefícios e canais de comunicação) para prever a mudança de comportamento. O modelo foi testado com base numa amostra recolhida em cinco países europeus, utilizando modelos de equações estruturais. Concluímos que os co-benefícios e os canais de comunicação, tanto de organizações como da internet, afetam significativamente a intenção de mudança de comportamento. Além disso, os nossos resultados enfatizam a importância do envolvimento do consumidor no tema da energia. Estes resultados são extremamente relevantes para organizações governamentais e de energia no sentido de aumentar a eficiência energética das residências.

PALAVRAS-CHAVE

Energia eficiente; Aparelho de aquecimento com eficiência energética; Comportamento do consumidor; Modelos de equações estruturais

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LIST OF ABBREVIATIONS AND ACRONYMS

EEHA Energy-efficient heating appliance

PLS-SEM Partial least squares – structural equation modeling

1. INTRODUCTION

Nowadays, in order to mitigate environmental problems consumers must make decisions regarding more efficient energy use (Beck et al., 2019). There are many mitigation efforts that should be implemented, from the adoption of renewable energy and energy-efficient appliances, to the adoption of new habits and policy regulations to control and better manage energy behaviors (Niamir et al., 2020). The residential sector itself represents about one-fifth of global energy consumption (Brounen et al., 2013), revealing the substantial impact on energy savings if efficient energy is largely adopted in the sector, and particularly the household adoption of energy efficient appliances. However, although government regulations strive to promote the adoption of green energy and more energy-saving habits, consumer involvement and willingness are crucial in the process of adopting more efficient energy (Sangroya & Nayak, 2017), supporting even more the need for studies of consumer behavior in this regard.

In the scope of EU energy savings, the propensity for purchasing energy-efficient appliances exerts a great influence, and understanding the drivers of appliance purchasing may help governments to better address campaigns and policies toward energy efficiency. However, the change of heating appliances does not occur frequently, as occupants tend to remain with the same heating appliance for long periods of time (Gaspar & Antunes, 2011). Also, the choice of home-heating requires a long-term perspective, as the investment in heating appliances is relatively capital demanding and the benefits may be felt only in a long term. Some analysts may even argue that this should be considered a type of infrastructure investment and, as with other investments, consumers may require a long-term loan (Bergman & Foxon, 2020). As a result, estimating these determinants might be a challenge (Baldini et al., 2018).

Although the motivation of researchers to understand what the determinants of energy-saving behaviors are (Nie et al., 2019), most studies in this area generally focus on one perspective at a time. Some of them investigate only the psychological factors, examining pro-environmental, social, and personal norms (Chen, 2016; Li et al., 2019), while some others emphasize the physical, technological, and/or socio-demographic components of the dwelling and consumer in order to understand energy consumption and investments (Braun, 2010; Kelly, 2011; Sunikka-Blank & Galvin, 2016). Only a few studies have addressed the topic of energy investment from both perspectives (Brounen et al., 2013; Niamir et al., 2020). Furthermore, those that do address it usually focus on energy behaviors and investments in a general way or are based on individuals who already made a heating appliance purchase in the last few years (Gaspar & Antunes, 2011; Lillemo et al., 2013). To fill this gap, we

developed a research model to explain behavior change (both attitude on heating equipment use and intention to change to an EEHA) that gathers contexts that are infrequently considered in combination. This model was developed based on literature review and qualitative interviews with experts from five European energy agencies and two European universities. The following contexts emerged from it: (1) triggers, (2) barriers, (3) engagement, and (4) house characteristics. To those, we leveraged the model with two more contexts rarely tested before in energy research: (5) co-benefits and (6) communication channels.

The contribution of this paper is threefold. First, we followed the suggestion of Venkatesh et al. (2013) to use mixed-methods, i.e., we use a qualitative approach with experts and structural equation modeling to test the emerged model. In doing so, our research is enriched with qualitative insights that enhance the model and demonstrates the importance of several technical and social components in predicting consumers' intention to change heating appliances. Second, our model includes two dependent variables, attitude on heating equipment use and behavior intention to change to an EEHA, investigating the direct and indirect effects on both variables. Our research thereby provides a more holistic investigation into the factors that affect consumer behavior intention compared with other studies that usually study only one variable individually and direct relations. Finally, for practitioners and policy-makers, this paper highlights important findings for a more effective formulation of campaigns and policies based on the results of the empirical model.

The paper is structured as follows. In the next section we provide the theoretical background pertaining to EEHA, as well as some studies about consumer behavior related to efficient energy. Section 3 presents the qualitative study, extending the literature review. In Section 4 the research model is built, and the hypotheses to be tested are described, preceded by empirical evidence regarding each context. Section 5 presents the methods. In Section 6 the results of the research model are presented. In Section 7 we discuss the findings of our work jointly with their theoretical and practical implications as well as limitations. Finally, in Section 8 we present the conclusions.

2. LITERATURE REVIEW

2.1. ENERGY-EFFICIENT HEATING APPLIANCE (EEHA)

In Europe, space heating occupies the first place as the most significant contributor to domestic energy consumption (European Union, 2012). Space heating accounts for 63.6% of the final energy consumption in households in the European Union, followed by water heating with 14.8%. Energy used for all other purposes, including space cooling, cooking, lighting, or other end uses, end up by representing less than 22% of final household energy consumption, as almost all energy products are used exclusively for space and water heating purposes, varying from 91.2% in oil products to 100% in derived heat (Eurostat). Therefore, there is a growing pressure to change to new fossil fuel reliant alternative forms of domestic heating (Hanmer & Abram, 2017). The necessity to improve the way energy is used in domestic buildings is affected by householders' energy behaviors (Haines et al., 2019), which in turn is also profoundly affected by the efficiency of the appliances (Gaspar & Antunes, 2011). In fact, one of the strategies for reducing energy consumption through space heating is the improvement of technologies and buildings (Wade et al., 2016). Moreover, structural factors such as the presence of efficient appliances proves to be a factor to increase the efficiency of households (Kavousian et al., 2015) and reduce residential energy consumption (Adua, 2020).

2.2. PRIOR RESEARCH

In the scope of theoretical foundations, we find some contexts that play an important role in the consumer decision-making process related to energy-efficient appliances. Even though many studies have addressed the determinants of energy-saving behaviors, few of them have focused on energy-saving investments, establishing a framework that encompasses several components (see Table 1). The studies focused on the social and psychological components of consumer behavior are often based on the following theories: theory of planned behavior (Lillemo et al., 2013), prospect theory (Ajzen, 2012), norm activation model (Schwartz, 1977), and values, beliefs, and norms theory (Stern et al., 1999). For example, Heutel (2019) concluded that the decision to invest in energy-efficiency entails some risk and uncertainty by itself, and that people thus behave according to the prospect theory. In other way, and focused more on general energy-saving behaviors, Chen (2016), based on the theory of planned behavior, concluded for a significant role of moral obligation to mitigate climate changes, in addition to attitude and subjective norm, while Li (2019), complemented by the norm activation model theory, concluded for the strong effect of opportunity followed by motivation. Also, based on careful energy use behaviors, Nie (2019) concluded for the relevance of subjective norms, encouraging

the diffusion of publicity on energy information and knowledge, creating a social public opinion, and directing pressure on the importance of pro-environmental behaviors.

On the other hand, some studies followed the more physical, economic, and/or socio-demographic contexts related to the house and the consumer. For example, Yang & Zhao (2015) concluded that family income positively moderates the relationship between energy-efficient and renewable energy equipment purchase attitude and behavioral intention, and in turn, subsidy incentives positively affect the moderator effect of family income. From a more socio-demographic perspective, Baldini (2018) concluded that the housing type, number of inhabitants, and age were strong predictors for purchasing energy efficient appliances, which is consistent with the findings of Braun (2010), who reported that the dwelling features are significant to determine the choice of the heating appliances. Also, Michelson and Michelsen & Madlener (2012) found differences between preferences of residential heating systems according to age of the house, indicating the relevance of socio-economic and demographic characteristics of the house as determinants of energy adoption choices. Besides that, and although few, some papers investigated both components. For example, Niamir (2020) found similar importance of monetary factors and the awareness and social norms on energy-related actions, by joining three theories to study energy-saving behaviors and investments in efficient appliances and house insulation. Also, Brounen (2013) investigated energy conservation behavior in households joining two perspectives, demographics of household and consumer attitudes toward energy conservation on energy-saving behaviors, finding significance for both. In sum, the adoption of efficient technologies is related not only to technological and economic factors like savings or characteristics, but also has to do with psychological aspects like engagement or social influence (Fornara et al., 2016).

Authors	Theory/Theories	Variables	Method	Data
Niamir et al. (2020)	Theory of planned behavior; Norm activation model	Country; Income; Gender; Education; Eco-comfort; Age; Tenure; Energy label; Type; Age of residence; Size; Electricity; Gas; Personal norms; Social norms	Regression (probit)	1790 household in Overijssel and Navarre
Heutel (2019)	Prospect theory	Prospect theory parameters and energy consumption variables	Regression	Online survey of 2045 U.S. individuals
Nie et al. (2019)	Theory of planned behavior	Attitude; Subjective norm; Perceived behavior control;	Structural equation modeling (SEM)	396 individuals in Changchun, China through an

		Careful-use intention; Careful-use behavior		online survey in 2016
Li et al. (2019)	Norm activation model; Theory of planned behavior	Ability; Behavior; Motivations; Opportunity	Structural equation modeling (SEM)	61 office buildings in the U.S.
Timm and Deal (2016)	Values beliefs norms theory; Theory of planned behavior	Energy attitudes; Energy behaviors; Demographic variables	Pre-post analysis; Mann-Whitney U test; Wilcoxon signed ranks test	Online survey in three colleges - students, facility managers, and staff
Yang and Zhao (2015)	Based on previous studies about the investment in energy efficiency topic	EERE equipment purchase attitude; EERE equipment Purchase behavioral intention; Socio-demographics; Family income; Subsidy incentive	Hierarchical linear regression	526 valid questionnaires from Beijing, Hefei, and Anyang
Chen (2016)	Theory of planned behavior	Mitigation attitude; Subjective norms; Perceived behavioral control; Moral obligation; Behavioral intentions	Confirmatory factor analysis (CFA); Structural equation modeling (SEM)	728 individuals
Brounen et al. (2013)	Based on previous studies about environmentalism and consumer choice	Home characteristics; Demographics; Ideology and attitudes; Energy literacy	Regression (logit)	1721 households
Michelsen and Madlener (2012)	Based on the most frequent explanatory variables in the reviewed studies about energy	Socio-demographic characteristics; Home characteristics; Spatial characteristics; RHS-specific attributes	Multinomial logit model	2240 responses of homeowners who had received a BAFA grant for installing a new RHS

Table 1 - Studies on energy efficiency and energy-efficient appliances

2.3. DRIVERS FROM LITERATURE

We based our variables' identification on prior research that applied behavior theories and technical components, gathering some of the most significant constructs and examine their relevance for the study of consumer behavior intention. While some works tried to test theories as some of the mentioned in the earlier section, others try to offer a more holistic view, combining different factors

(Niamir et al., 2020). This later was the followed approach. We figure out four contexts: (1) triggers context, where energetic efficiency was identified, representing the expected increase in the house' energetic efficiency through changing to an EEHA, already proved in several works (Wade et al., 2016; Yohanis & Mondol, 2010). Savings (Michelsen & Madlener, 2012) and energetic label (Howarth et al., 2000; Yang & Zhao, 2015) were also considered relevant; (2) in the context of barriers, operation and maintenance costs were considered relevant (Sopha & Klöckner, 2011; Tsoka et al., 2018). In fact, the use of terms such as drivers or barriers have already been mentioned in some studies in the energy area (Achtnicht & Madlener, 2014; Edling & Danks, 2018); (3) Regarding the engagement context, the level of consumer engagement and interest was considered relevant. This element can be seen as a proxy of energy awareness and literacy regarding energy topics, already studied in several articles (Brounen et al., 2013; Koirala et al., 2018; Surulivel et al., 2018). Social influence, which relates to the well-researched construct of social norms, used in several theories was also identified (Chen, 2016; Niamir et al., 2020); (4) Referring to the context of house characteristics, house age (Brounen et al., 2013; Noonan et al., 2015) and houses' energy class (Niamir et al., 2020) were considered relevant.

3. QUALITATIVE STUDY

To increase the understanding of the phenomena of heating equipment change, a mixed-methods methodology was applied (Venkatesh et al., 2013). We decided to follow an approach similar to that of Mingers (2001). As such, after identifying the theoretical constructs, we conducted a qualitative exploratory study followed by a confirmatory study. Since the purpose of executing qualitative interviews is to identify and test the theoretical constructs already found in literature and understand the existence of others, a qualitative study followed by a quantitative is appropriate for this case (Venkatesh et al., 2013), following a sequential qualitative-quantitative design (Venkatesh et al., 2016). This work is quantitative dominant and the purpose of this mixed-methods approach is developmental, so after identifying the theoretical constructs, an exploratory study based on semi-structured interviews was undertaken. Since our work is based on five European countries and their characteristics, the sample interviewees were identified with the purpose of meeting the characteristics of those countries. As such, the selected individuals represent different international and European energy agencies. See Appendix A for more information about the interviewees. The interviews were carried out during the HARP project consortium, and the number of interviews was based on saturation (Fusch & Ness, 2015). Data saturation is reached when there is enough information to replicate the study, there is no more ability to obtain new information, and further coding is no longer feasible (Fusch & Ness, 2015). The chosen method to achieve data saturation was by having a saturation grid, where the researcher listed the major topics vertically and noted the interviews on the horizontal (Brod et al., 2009). The personal interviews were equally structured to guarantee the consistency of results. Seven interviews were conducted. Qualitative data was content analysed based on general themes that represented the constructs of the research model. As result, the identified constructs were validated, based on the frequencies of responses. This qualitative approach also raised the importance of two additional contexts: (5) co-benefits and (6) communication channels (see Table 2 presenting factors of consumer intention to change to an EEHA identified by the interviewees).

Low frequency (1-3 interviews)	**Medium frequency (4-5 interviews)**	**High frequency (6-7 interviews)**
• Habit – it is usual to use EEHAs • Price value	• Willingness to pay for co-benefits • Energy efficiency • Engagement • Social influence • Operation and maintenance	• Energetic label • Houses characteristics • EEHA savings • Level of co-benefits (value) • Communication channels

Table 2 - Factors of consumer intention to change to an EEHA identified by the interviewees

Concerning co-benefits, the importance of measuring these in terms of value and willingness to pay arose from the interviews with experts. Few articles explore them, which can be felt at the building level (e.g., increased thermal comfort, improved aesthetics, fewer problems related to the useful living area) and society level (e.g., health effects, impact on climate change, energy use) (Ferreira et al., 2017). These co-benefits are especially relevant for policymakers in the development of policies and campaigns, taking into consideration the possible crossed impacts on several levels (Ferreira & Almeida, 2015). Co-benefits can be measured from two different perspectives – simple contingent valuation and willingness to pay (Ferreira et al., 2017), which is aligned with the interviewees' vision of evaluating co-benefits in two perspectives. From this, two constructs were created: co-benefits in general and co-benefits investment.

Regarding communication channels, from qualitative interviews, this is an important variable that influences consumer awareness, and it is an important tool in the decision-making process of changing to an EEHA. Although few studies encompass the communication component in the understanding of consumer behavior, the reception of information from mass media or other people positively impacts the probability of selecting heating systems (Franceschinis et al., 2017). Based on the theory of diffusion of innovation (Rogers, 2010), Franceschinis et al. (2017) suggest several kinds of communication: mass media, including TV, radio and newspaper and interpersonal ones, that consists of two-way communication between two or more subjects and usually is more effective at creating or changing attitudes on subjects. Three factors, namely, media, organizations, and web media, were identified from the expert interviews.

4. RESEARCH MODEL

Our holistic research model is grounded on a combination of literature review and qualitative study inputs. Consequently, is based on **six contexts** considered as potential influencers of behavior intention to change to an EEHA. Based on the literature, we selected **four contexts**: **(1)** energy efficiency, representing expected increase in house energy efficiency, energetic label and savings as the **triggers' context**; **(2)** operation and maintenance as the **barriers' context**; **(3)** Engagement and social influence were nominated in the **engagement context**; **(4)** house age and house' energetic label for the **house characteristics context. Two more contexts,** based on a qualitative study, emerged: **(5)** co-benefits in general and co-benefits investment as the **co-benefits' context**; **(6)** media communication channels, organization communication channels, and web media communication channels as the **communication channels' context**. Figure 1 presents the research model for consumer behavior change. The next sub-sections present the roles of each context and the research hypotheses.

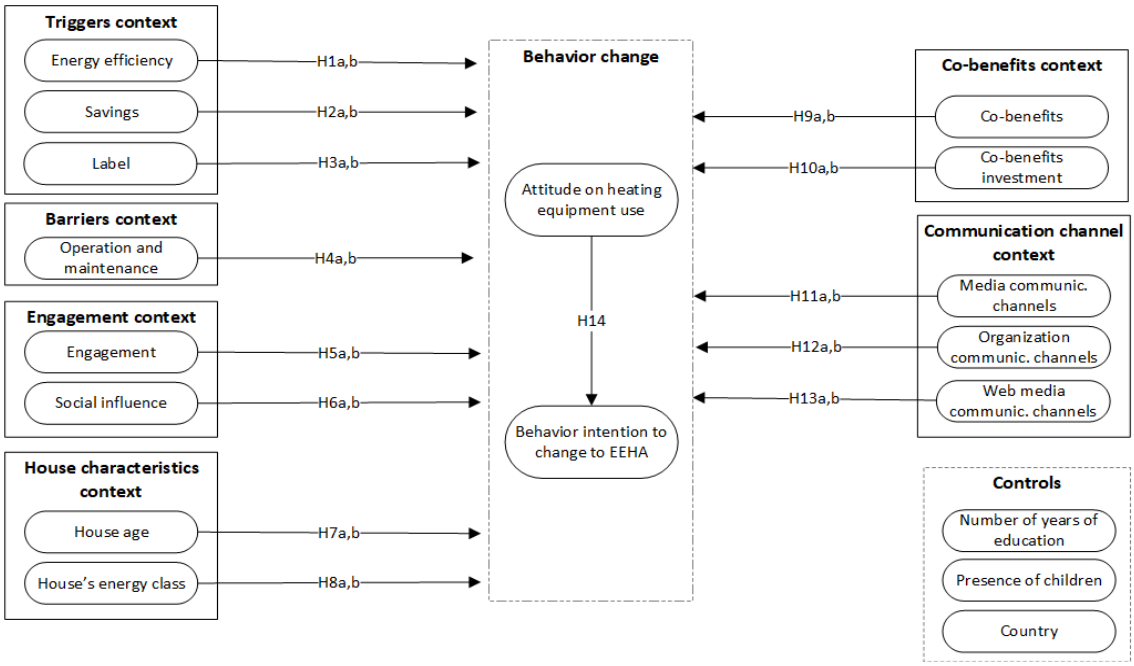

Figure 1 - Research model

4.1. TRIGGERS CONTEXT

The triggers context is based on variables that can be positive drivers for consumers to change their heating appliances, including energy efficiency (EE), savings (Sav), and label (Lab). As the literature suggests, these variables are three of the ones that consumers consistently take into consideration when adopting energy-saving behaviors or investments. Energy efficiency (EE) stands for the expected increase of the energetic efficiency of the house through the acquisition of an EEHA. Accordingly to

Wade et al. (2016), one of the strategies to reduce energy consumption is via the acquisition of efficient appliances. Also, Prete et al. (2017) suggest that implementing energy-efficient measures in residential buildings, which require the use of innovative materials and installation of efficient appliances, is one of the most effective strategies to decrease household energy consumption, emphasizing the importance of this construct. As for energy savings, this is a prevalent factor when studying efficient energy adoption. Michelsen and Madlener (2012) suggest that being aware of possible monetary and energetic savings have shown to be great predictors of energy-saving behaviors. Moreover, Ek and Söderholm Patrik (2010), conclude that promoting more concrete energy savings measures is more effective than general information, suggesting the importance of this variable in consumers' energy-efficient investments. Also, labelling is seen as one of the strategies to overcome some barriers on appliances purchases (Howarth et al., 2000), since consumers have a high level of awareness of the energy label in appliances (Sammer & Wüstenhagen, 2006). Mills and Schleich (2012) suggest that appliance energy-efficiency labels could also be modified to include information on operating costs, reinforcing that they are a sound strategy towards efficient energy adoption and a relevant aspect for energy agencies. Based on this, the hypotheses are:

H1a: Energy efficiency will positively influence the attitude on heating equipment use
H1b: Energy efficiency will positively influence the behavior intention to change to an EEHA
H2a: Savings will positively influence the attitude on heating equipment use
H2b: Savings will positively influence the behavior intention to change to an EEHA
H3a: Label will positively influence the attitude on heating equipment use
H3b: Label will positively influence the behavior intention to change to an EEHA

4.2. BARRIERS CONTEXT

Regarding the context of barriers, many articles report an impact of operation and maintenance (OM) on efficient energy investments. For example, Tsoka (2018) conclude that maintenance issues are constraints to the investment in efficient appliances, in the case of efficient building facades. Also, (Steg, 2008)Steg (2008) suggests that when saving energy involves, among others, high costs in terms of effort or convenience, then this will negatively affect energy-saving behaviors. In addition, the ease of use and maintenance issues were also studied by Michelsen & Madlener (2012), suggesting the importance of these in the decision to purchase the heating appliance. Based on this, two additional hypotheses are:

H4a: Operation and maintenance will negatively influence the attitude on heating equipment use

H4b: Operation and maintenance will negatively influence the behavior intention to change to an EEHA

4.3. ENGAGEMENT CONTEXT

Several studies demonstrate that consumer engagement has a significant effect in energy-saving behaviors. In our work, we study the role of engagement (EG) and social influence (SI) in consumer behavior change. The engagement variable stands for individuals' awareness of and interest in the topic of efficient energy and EEHA. Literature has shown the relevance of personal interest and awareness among the behavior factors in energy choices (Niamir et al., 2020). Many researchers have studied environmental awareness and energy literacy as an important factor toward energy-saving choices (Braun, 2010; Brounen et al., 2013; Haines et al., 2019). Also, social influence presents an impact on consumer energy-saving behaviors. Fornara (2016) posit that the role of social influence is important in predicting the intention to invest in household renewable energy devices. Furthermore, the work of Chen (2016) refers to both factors of engagement and social influence, concluding that individuals who have a more positive attitude toward the mitigation of global climate change show some interest in the topic, and when people important to them encourage them to adopt that kind of behavior the intention to engage in energy savings will increase. Therefore, the following is also hypothesized:

H5a: Engagement will positively influence the attitude on heating equipment use
H5b: Engagement will positively influence the behavior intention to change to an EEHA
H6a: Social influence will positively influence the attitude on heating equipment use
H6b: Social influence will positively influence the behavior intention to change to an EEHA

4.4. HOUSE CHARACTERISTICS CONTEXT

Regarding house characteristics, several studies report the relevance of this context toward heating appliance choice and efficient energy choices. These characteristics refer to the structural attributes well studied in several articles (Brounen et al., 2013; Noonan et al., 2015). For example, Niamir (2020) concluded that the residence characteristics such as house age (HA) and house's energy class (HEC) were important factors that influence the willingness to switch to a green provider, while the owners of older residences are more likely to switch as well as if the residence has a lower energy label. Also, Braun (2010) concluded that the dwelling attributes are important determinants of the space heating appliance type. Thus, additional hypotheses are:

H7a: House age will positively influence the attitude on heating equipment use

H7b: House age will positively influence the behavior Intention to change to an EEHA

H8a: House's energy class will negatively influence the attitude on heating equipment use

H8b: House's energy class will negatively influence the behavior intention to change to an EEHA

4.5. CO-BENEFITS CONTEXT

From the qualitative study, the importance of co-benefits emerged as a driver for consumers' intention to change to an EEHA – both co-benefits (CB) in general and co-benefits investment (CBInv). Co-benefits are related to the benefits that the change to an EEHA can bring to individuals as well as buildings (Ferreira et al., 2017). This can be measured either qualitatively by seeking to understand the importance of the co-benefits (co-benefits) or quantitatively by understanding the willingness to pay for those same benefits (co-benefits investment), which sometimes may not be the same (Ferreira et al., 2017). Several studies have also sought to determine the most-valued consumer benefits on heating appliance purchase and consumption (Banfi et al., 2008; Wolff et al., 2017). From the qualitative study emerged the constructs co-benefits, measuring the value of co-benefits, and co-benefits investment, representing the willingness to pay for these. These constructs are formative since their items are not necessarily correlated as a reflection of the construct. Instead, they cause the construct. Based on this, the following hypotheses are made:

H9a: Co-benefits will positively influence the attitude on heating equipment use

H9b: Co-benefits will positively influence the behavior intention to change to an EEHA

H10a: Co-benefits investment will positively influence the attitude on heating equipment use

H10b: Co-benefits investment will positively influence the behavior intention to change to an EEHA

4.6. COMMUNICATION CHANNELS CONTEXT

From the qualitative study, the importance emerged of including three types of communication channels in the model: media communication channels (MCC), organization communication channels (OCC), and web media communication channels (WCC). Knowing that communication channels have a considerable impact on how information is made available, it is important to measure the effect of those channels on consumers when it concerns buying efficient heating appliances, especially for energy organizations and agencies responsible for campaigns and incentives toward efficient energy investments. Although not deeply explored, it is expected that information sourced from other people and from media should be influential for individuals (Franceschinis et al., 2017). Moreover, not only

may the media and web media have an impact, but organizations related to energy may also, including both energy agencies or professionals and installers. Indeed, Wade (2016) studied how these professionals play a bridging role between heating systems and consumers, understanding their substantial influence in the selection of heating products. From these domains, media, organization, and web media communication channels emerged. These constructs are formative since their items are not necessarily correlated as a reflection of the construct. Instead, they cause the construct. From this, the following hypotheses are advanced:

H11a: Media communication channels will positively influence the attitude on heating equipment use
H11b: Media communication channels will positively influence the behavior intention to change to an EEHA
H12a: Organization communication channels will positively influence the attitude on heating equipment use
H12b: Organization communication channels will positively influence the behavior intention to change to an EEHA
H13a: Web media communication channels will positively influence the attitude on heating equipment use
H13b: Web media communication channels will positively influence the behavior intention to change to an EEHA

4.7. BEHAVIOR CHANGE CONTEXT

This context comprises attitude on heating equipment use (Att) and behavior intention to change (BIC). When studying the behavior intention of individuals, it is usual to study the individuals' attitudes. For example, Yang & Zhao (2015) used purchase attitude as an explanatory construct of purchase behavioral intention. In many studies attitude is seen to be a significant predictor of behavior (Fornara et al., 2016; March et al., 2015). According to the theory of planned behavior (Ajzen, 2012), attitude is an explanatory variable of intention. Attitudes are not directly related to behavior, but rather with intentions (B. Mills & Schleich, 2012) and can be seen as the evaluation of individuals regarding some behavior (Yang & Zhao, 2015). In our case it refers to the positive or negative evaluation of actually changing to an EEHA.

H14: Attitude on heating equipment use will positively influence the behavior intention to change to an EEHA

4.8. CONTROLS

The study of consumer behavior is usually controlled for some variables, especially socio-demographic parameters and, in the particular case of energy, house demographics (Davis, 2011; Erell et al., 2018; B. F. Mills & Schleich, 2009; Yang & Zhao, 2015) that used age, gender, education level, but also the age of the household and the presence of children. The number of years of education, the presence of children in the household, and the country were used as control variables in the model.

5. METHODOLOGY

5.1. MEASUREMENT

The confirmatory study involved the collection of quantitative data through a survey approach to test the research model. An online survey was conducted in order to collect the responses from all five countries. The questionnaire was composed of the items of each identified construct (see Appendix B). Constructs were adapted from published literature regarding efficient energy and consumer behavior and the findings of the qualitative study. Most of the questions have a seven-point numerical scale (ranging from 1 – completely disagree to 7 – completely agree). Initially, the questionnaire was developed in English and Portuguese with a review of academic researchers and university staff that validated both questionnaires. Then, the questionnaire was translated into the other four main languages of the countries in the study – French, Italian, German, and Spanish. Several versions were reworded from each language to English and vice versa, guaranteeing the equivalence of meaning in all translated versions (Cha et al., 2007). In addition, we undertook a pilot survey with 200 responses. These first results showed that the items were adequate and measured the constructs well, demonstrating the validity and reliability of the questionnaire.

5.2. DATA

The questionnaire was administered in the five European countries in the study over five months, from October 2019 to February 2020. Residents from each country were randomly selected in each country. A total of 2371 responses were collected. After data cleansing and the removal of incomplete responses, a sample of 1611 individuals were retained. We also examined the common-method bias in two ways. First, using Harman's one-factor test (Podsakoff et al., 2003) none of the indicators individually explain more than 50% of the variance. Second, a theoretically irrelevant marker variable was added (Lindell & Whitney, 2001), presenting a maximum shared variance with other variables of 0.055 (5.5%), which is a reasonable value (Johnson et al., 2011). As a result, no significant common method bias was indicated.

As shown in Table 3, 31% of respondents range from 18 to 39 years, and 69% are older than 40. Quotas were set in order to have similar proportions between each county sample and the respective populations. In addition, a Chi-squared test was conducted for differences in probabilities. Also, to ensure that samples were sufficiently income balanced, median equivalized monthly household net income per country was also considered. The confidence interval for this measure was calculated for each country, showing in all countries except for Portugal, no differences, as the population parameter

is in the confidence interval calculated with the samples of each country (see Appendix C – Table C.1). Only Portugal presents a slight difference in age and income. This may be due to the fact that this is a very aged country and with much lower incomes when compared to the other countries under study. However, the target population in these types of studies of energy appliances tends to have a somewhat higher income (Yang & Zhao, 2015) , which implies a slightly higher income in the Portuguese sample when compared to the general population. Also, Portugal is characterized by a low level of digital literacy, especially among the elderly, which is the main reason for having more young individuals who answered to the online questionnaire. A calculation for the minimum sample size was also performed using the sample size formula for an infinite population. The prevalence (p) for each country as the percentage of respondents that were willing to change their heating appliance was obtained resorting to a study conducted by EUROGAS in October of 2019 (Owen & Alloh, 2019). A level of precision (d) of 5% was also assumed (Naing et al., 2006). The necessary minimum number of complete responses was achieved using this calculation. As demonstrated in Table C.2 (Appendix C), all countries exceeded the minimum number of complete responses.

The average number of years of education is 15.3 years, showing a somewhat higher level of education compared to the total population, which is usual in studies of energy-efficient investments (Koirala et al., 2018; Nie et al., 2019). Also, 40% of respondents have no children. The number of years of education and the presence of children were used as control variables, preserving the impacts of the explanatory variables regardless of the level of education or presence of children. The majority of the respondents were the owners of their house and the ones responsible for the decision of installing or changing their heating equipment solution, which is in accordance with the majority of studies regarding energy-saving behaviors, in which the sample is usually composed of homeowners (Koirala et al., 2018; Musti et al., 2011; Wilson et al., 2015).

Sample characteristics (n=1611)	Descriptive statistics
Age	
18-39	31%
≥ 40	69%
Gender	
Female	41%
Male	59%
Responsible for the decision to change to an EEHA	77%
Homeowner	78%
Children (1 = have children; 0 = don't have children)	40%
Number of years of education	15.3
Country	
France	23%
Germany	11%
Italy	22%
Portugal	16%
Spain	28%

Table 3 - Descriptive statistics of the sample

6. RESULTS

The partial least squares (PLS) technique was used to estimate the research model. This method was chosen since it is a technique used to test models that have not been tested before (Ke et al., 2009), which is the case of our research model as an explanatory research to predict behavior change. PLS is also a technique that allows having formative indicators measuring the constructs (Goo et al., 2009) and does not require any restrictive assumption regarding distribution (Fornell & Bookstein, 1982). All these requirements were verified, establishing the suitability of the PLS method. First, the measurement model will be analyzed regarding discriminant validity and reliability, and then the structural model will be tested. For these purposes, Smart PLS 3.0 was used (Ringle, Christian M., Wende & Becker, 2015).

6.1. MEASUREMENT MODEL

Several measures were analyzed to assess the measurement model. Table 4 shows the mean and standard deviation of the reflective constructs, as well as the composite reliability (CR) and the average variance extracted (AVE). All constructs present a CR higher than 0.7, showing the reliability of scales, and an AVE higher than 0.5 confirming convergent validity (Fornell & Larcker, 1981; Hair et al., 2011). The Fornell-Larcker criterion, cross-loadings, and Heterotrait-Monotrait Ratio (HTMT) were used to assess discriminant validity. The Fornell-Larcker criterion ensures discriminant validity if the diagonal elements, representing the square root of AVE, are higher than the correlations between the constructs (Fornell & Larcker, 1981). This criterion is assured, as noted in Table 4. Table 8 in Appendix D shows the loading and cross-loadings. As observed, all loadings are higher than the cross-loadings, satisfying the condition (Chin, 1998). Table 9 in Appendix D represents the HTMT, whose values are lower than 0.9, confirming discriminant validity between the reflective constructs. Consequently, the reflective constructs can be used to test the structural model.

	Mean	STD	CR	EE	Sav	Lab	OM	EG	SI	HA	HEC	Att	BIC
EE	6.104	1.356	1.000	**1.000**									
Sav	5.952	1.201	0.894	0.489	**0.861**								
Lab	6.132	1.135	0.927	0.452	0.491	**0.900**							
OM	3.162	1.625	0.938	-0.247	-0.143	-0.157	**0.914**						
EG	4.355	1.541	0.960	0.233	0.120	0.218	-0.184	**0.961**					
SI	3.710	1.741	0.974	0.195	0.153	0.215	-0.088	0.601	**0.962**				
HA	4.305	1.924	1.000	0.094	0.066	-0.029	-0.072	-0.026	0.027	**1.000**			
HEC	3.332	2.600	1.000	0.016	-0.074	0.020	-0.078	0.306	0.249	-0.239	**1.000**		
Att	3.984	1.725	0.884	0.314	0.263	0.304	-0.159	0.314	0.311	0.056	0.023	**0.890**	
BIC	4.875	1.660	0.925	0.430	0.320	0.360	-0.287	0.457	0.439	0.084	0.121	0.680	**0.897**

Table 4 - Mean, standard-deviation, CR, and Fornell-Larcker table. The diagonal elements are the square-root of AVE. EE – Energy efficiency; Sav – Savings; Lab – Label; OM – Operation and maintenance; EG – Engagement; SI – Social influence; HA – House age; HEC – Houses' energy class; Att – Attitude on heating equipment use; BIC – Behavior intention to change

Concerning to formative constructs, it was necessary to assess the multicollinearity and significance and relevance of indicator weights (Hair et al., 2011). The variance inflation factor (VIF) was performed to assess multicollinearity. Table 5 present the VIF values lower than 3.3, indicating no multicollinearity issues (Lee & Xia, 2010). Table 5 also shows the weights and loading of indicators. All the indicators that do not have significant weights have loadings higher than 0.5, confirming the significance and relevance of indicator weights. Consequently, the formative constructs can also be used to test the structural model.

		Mean	STD	Weights	Loadings	VIF
Co-benefits	**CB1**	5.623	1.737	0.274***	0.589***	1.516
	CB2	5.277	1.675	-0.214***	0.227***	1.395
	CB3	5.312	1.696	0.261***	0.591***	1.537
	CB4	5.782	1.476	-0.148*	0.501***	1.819
	CB5	6.081	1.354	0.854***	0.946***	1.634
Co-benefits investment	**CBInv1**	252.943	236.461	0.403***	0.801***	2.674
	CBInv2	249.765	234.095	-0.089	0.699***	2.897
	CBInv3	218.981	223.278	0.028	0.658***	3.137
	CBInv4	209.052	222.694	0.125	0.637***	3.077
	CBInv5	195.953	207.858	-0.150	0.611***	2.681
	CBInv6	262.967	242.853	-0.042	0.671***	2.356
	CBInv7	186.082	200.868	0.343***	0.652***	2.238
	CBInv8	223.899	223.320	-0.230**	0.550***	2.378
	CBInv9	270.643	236.566	0.134	0.677***	1.982
	CBInv10	297.098	246.125	0.634***	0.902***	2.268
Media communication channels	**MCC1**	3.672	1.762	0.320*	0.848***	2.144
	MCC2	3.344	1.784	0.295	0.904***	3.046
	MCC3	3.608	1.871	0.498***	0.926***	2.478
Organization communication channels	**OCC1**	4.627	1.894	0.481***	0.768***	1.207
	OCC2	5.061	1.814	0.573***	0.854***	1.426
	OCC3	4.975	1.653	0.019	0.595***	2.143
	OCC4	4.538	1.691	0.226**	0.577***	1.908
Web media communication channels	**WCC1**	4.979	1.575	0.624***	0.868***	1.243
	WCC2	3.577	1.802	0.553***	0.829***	1.243

Table 5 - Mean, standard-deviation, weights, loadings and VIF of formative construct indicators (* p-value <0.10; ** p-value<0.05; *** p-value<0.01)

6.2. STRUCTURAL MODEL

Before analysing the structural model, we tested the multicollinearity between all constructs, using the variance inflation factor (VIF). All VIF values are below 3.3, demonstrating no multicollinearity issues among variables (Lee & Xia, 2010). The structural model, represented in Figure 2, presents the

total effects and the explained variation. Bootstrapping with 5000 iterations of resampling was performed to assess the significance of total effects (Hair et al., 2011). Total effects include the direct effects over behavior intention to change to an EEHA plus the indirect ones through the attitude on heating equipment on use (Henseler et al., 2009).

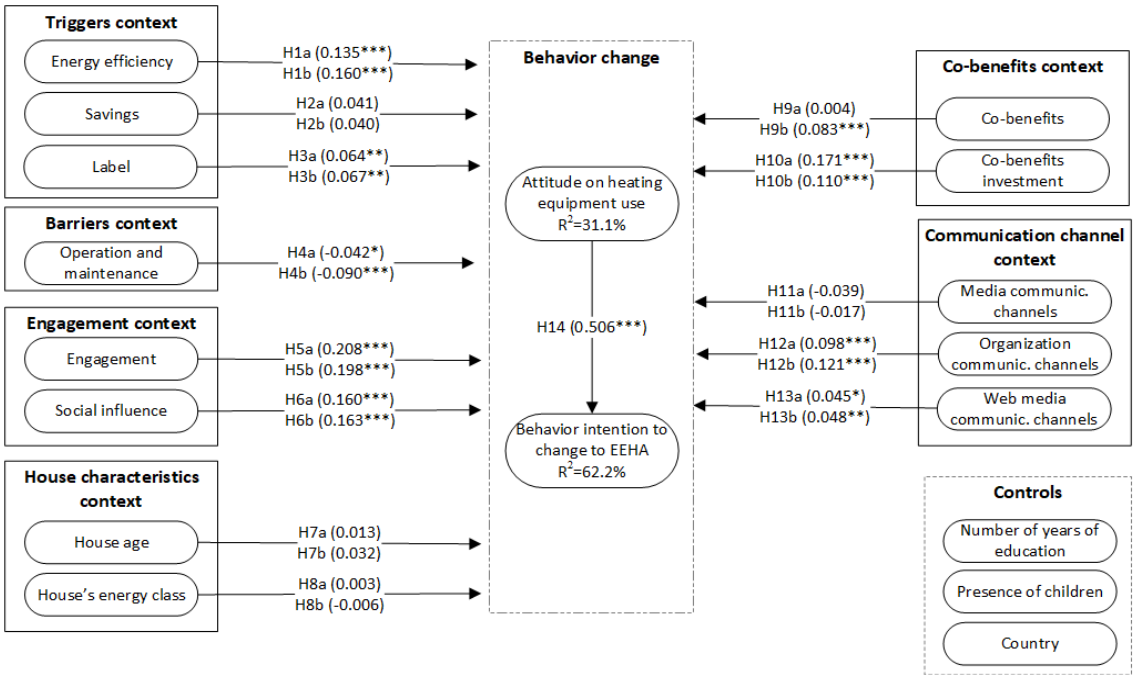

Figure 2 - Structural model for behavior intention to change. Total effects (* p-value <0.10; ** p-value<0.05; *** p-value<0.01)

Our model explains 62.2% of the variation on behavior intention to change to an EEHA. From the triggers' context, the results indicate that energy efficiency is significant for both attitude on heating equipment use ($\hat{\beta}$a=0.135; p<0.01) and behavior intention to change to an EEHA ($\hat{\beta}$b=0.160; p<0.01), verifying H1a and H1b. Savings result to be not statistically significant for both attitude on heating equipment use and behavior intention to change to an EEHA. Otherwise, label presents statistical significance for attitude on heating equipment use ($\hat{\beta}$a=0.064; p<0.05) and behavior intention to change to an EEHA ($\hat{\beta}$b=0.067; p<0.05). H3a and H3b are established. Concerning barriers, operation and maintenance is statistically significant for both dependent variables, verifying H4a and H4b ($\hat{\beta}$a= -0.042; p<0.1) ($\hat{\beta}$b=-0.090; p<0.01). The results also show a statistically significant effect on both constructs of the engagement context. Engagement ($\hat{\beta}$a=0.208; p<0.01) ($\hat{\beta}$b=0.198; p<0.01) and social influence ($\hat{\beta}$a=0.160; p<0.01) ($\hat{\beta}$b=0.163; p<0.01) have statistically significant effects for both

dependent variables. H5a, H5b, H6a, and H6b are confirmed. House characteristics otherwise showed not to have statistically significant effects, not confirming the effects of house age and houses' energy class (H7a, H7b, H8a, and H8b). Regarding the co-benefits context, this construct only has a significant effect in behavior intention to change ($\hat{\beta}$b=0.083; p<0.01). Co-benefits investment is one of the constructs with a statistically significant high effect in both dependent variables ($\hat{\beta}$a=0.171; p<0.01) ($\hat{\beta}$b=0.110; p<0.01). From the communication channels, the ones with a statistically significant effect in attitude on heating equipment use and behavior intention to change are the organization communication channels ($\hat{\beta}$a=0.098; p<0.01) ($\hat{\beta}$b=0.121; p<0.01) and the web media communication channels ($\hat{\beta}$a=0.045; p<0.1) ($\hat{\beta}$b=0.040; p<0.05), validating H12a, H12b, H13a, and H13b. As expected from other studies, attitude on heating equipment is statistically significant for behavior intention to change to an EEHA ($\hat{\beta}$=0.506; p<0.01), confirming H14.

7. DISCUSSION

As the need to mitigate environmental problems increases, the necessity to understand consumer behavior regarding efficient energy increases too. The results of our work allow one to understand what drives consumers to change to an EEHA, something, to the best of our knowledge, not yet reported in other studies. Understanding the consumer determinants to change to an EEHA is important for an effective formulation of campaigns and communication strategies towards the consumer adoption of more efficient heating appliances.

Within the triggers context, our results confirm the importance of the energetic label as well as the awareness of increased energy efficiency in homes if an EEHA is acquired. Energy efficiency has the third-highest impact on behavior intention to change, demonstrating the importance for consumers to have a more energy-efficient house, many times by the means of efficient/energy appliances acquisition. This result reinforces the increasing interest in obtaining a smart house in terms of energy efficiency and environmental friendliness, already studied in other articles (Balta-Ozkan et al., 2014). Also, the presence of the energetic label on the appliance is an identified driver for people to change their heating equipment. Results prove that consumers, engaged in this topic, pay attention to appliances' energetic label and its identification is a clear motivation to acquire an EEHA, as confirmed in qualitative interviews. From their experience, experts argued that the energetic label is still a high-valued factor for acquiring heating appliances. Savings were not statistically significant to both dependent variables. This result suggests that consumers are giving more importance to benefits related to their personal health and environmental wellbeing, instead of the actual money they can save with other heating solutions.

From our results, engagement is the one with the strongest effect in both dependent variables. This suggest that the more energy awareness and interest by the consumer in the topic, the more positive is the attitude towards the change of the heating equipment, leading to the intention to change to an EEHA. This finding is supported by earlier works (Vogiatzi et al., 2018). Additionally, the influence of known and valued people by the consumer show to have a great impact in behavior change. This insight demonstrates the importance of what is usually called word-of-mouth communication, either personal or online. This finding is also supported by earlier research (Chen, 2016). This proves that the change to an EEHA is related to structural factors but also with cognitive and affective ones.

Operation and maintenance reveal a negative impact in both variables of the behavior change context, confirming earlier studies (Steg, 2008). In fact, high efforts relating to the use and maintenance of an

appliance will negatively influence the propensity to change to an energy-efficient one. Additionally, our results showed that either house age or house energy class does not have a significant effect in both dependent variables when tested with other contexts.

Concerning co-benefits, the greatest effect proves to be in co-benefits investment. The willingness to pay for co-benefits, like thermal comfort, reduced noise, and avoidance of health problems, is a great predictor of attitude and intention to change. This proves that people are willing to pay to ensure those co-benefits, which in turn may be provided by an efficient heating appliance. Moreover, the co-benefits construct also has a positive effect on the behavior intention to change, supporting the importance of those and their promotion.

From communication channels, our results suggest the importance of organization and web media channels, both for attitude and intention. This confirms the importance of energy agencies and organizations, as well as the professionals and installers, already supported in other studies (Wade et al., 2016). In the topic of energy and EEHA, this type of communication presents one of the strongest impacts in driving to consumer intention to change to an EEHA. Furthermore, web media communication channels reflect the current importance of the internet and online sources of information as well as related mobile applications. This result is also aligned with the importance of engagement and social influence, more and more through web means. This finding is noteworthy as it barely has been included in earlier studies and it can be used to help agencies and policy about the channels to address consumers in communication actions about efficient-energy transitions.

In addition to the results presented, a comparison between the sample countries was also performed. The results are summarized in Table 6. In all five countries, the strongest significant effects in the individual models per country were in most cases the ones that are also significant in the model with all sample observations. Co-benefits investment appears as statistically significant for all countries regarding behavior intention to change, and all except France for attitude on heating equipment use. This outcome reinforces the strong impact of this variable, already confirmed. Our findings also show engagement as an important driver of behavior intention to change in all countries except for Germany. Organization communication channels and operation and maintenance also have a significant effect on behavior intention to change in three of the five countries. The results reinforce the importance of these variables, whereby although differing in the effect magnitude, they are indeed explicative in almost all countries. Consumer engagement seems to be one key element toward the change to an EEHA, especially when emphasizing the possible benefits consumers may achieve in their own households. This finding suggests that, overall, people are willing to invest in appliances when

there are clear benefits to both their house and personal health and wellbeing. Ultimately, changing an EEHA can be seen as an investment in their wellbeing, and this should not be ignored when formulating strategies or policies toward the increase of energy efficiency in the residential sector. Although this last conclusion proves to be transversal to all countries under study, it should be noted that the way consumers are approached may differ from country to country. For example, Germany is particularly interesting for its strong environmentalism value leveraged by the government regulations in sustainable energy matters (Wunderlich et al., 2019), which may not be true for all countries. Moreover, considerable differences exist among European countries. For example, Mediterranean countries have significantly lower heating needs when compared to center or northern countries (Martinopoulos et al., 2018). It is worth noting that in both Spain and Italy the energy efficiency construct reveals to have a strong effect, contrary to the others. This finding suggests then that in these countries (Mediterranean), the change to an EEHA is also much motivated by the intention to increase overall house's energetic efficiency, since the need to heat the house is not so prominent. This may imply a single fact: overall, consumers are willing to buy appliances for their "efficiency" characteristic, and if so, this can be true for any other energy efficient appliance. Increasing houses' energetic efficiency also has shown to be a relevant added value to houses, especially in the real-estate market. Several studies have proved that investments in energy performance really translate into economic value and higher prices for real estate (Encinas et al., 2018; Popescu et al., 2011). Again, co-benefits prove their relevant role in the intention to change to efficient appliances. Also, media communication channels reveal to be significant to both attitude and intention in Spain but only for attitude in France. This finding suggests that media communication tends to vary from country to country in terms of the type of information and the way it is presented and spread. It is reasonable that the influence of these channels differs between countries. This finding suggests the value of having a unified strategy or framework of communication in Europe, that then grows on its specifications according to the characteristics of each country.

Construct	Path	Total Effects				
		France	Germany	Italy	Portugal	Spain
Energy efficiency	EE -> Att	0.091	0.088	0.067	0.086	0.154***
	EE -> BIC	0.119	0.093	0.142**	0.094	0.144***
Savings	Sav -> Att	0.093	0.003	0.027	0.069	0.064
	Sav -> BIC	0.184***	-0.037	0.036	0.074	0.011
Label	Lab -> Att	0.161***	-0.007	0.013	0.073	0.041
	Lab -> BIC	0.099**	-0.014	0.059	0.073	0.040
Operation and maintenance	OM -> Att	-0.098*	-0.046	0.034	-0.146***	-0.089**
	OM -> BIC	-0.020	-0.102**	0.028	-0.182***	-0.150***
Engagement	EG -> Att	0.282***	0.145*	-0.011	0.090	0.190***
	EG -> BIC	0.206***	0.023	0.122**	0.110*	0.254***
Social influence	SI -> Att	0.032	0.126*	0.057	0.203***	0.227***
	SI -> BIC	0.035	0.125**	0.126*	0.077	0.196***

House age	HA -> Att	0.035	-0.13**	0.023	0.095*	0.014
	HA -> BIC	0.066*	-0.053	-0.008	0.127**	0.037
Houses' energy class	HEC -> Att	0.057	-0.138**	-0.008	0.070	0.009
	HEC-> BIC	0.020	-0.123**	-0.057	0.095	0.038
Co-benefits	CB -> Att	-0.019	0.227**	0.082	0.036	0.011
	CB -> BIC	0.070	0.350***	0.041	0.070	0.080
Co-benefits investment	CB inv -> Att	0.031	0.178**	0.342***	0.197***	0.222***
	CB inv -> BIC	0.100**	0.165***	0.226***	0.186***	0.131***
Media communication channels	MCC -> Att	-0.098**	0.006	-0.049	-0.020	0.133**
	MCC -> BIC	-0.022	0.027	0.007	0.056	0.110**
Organization communication channels	OCC -> Att	0.256***	0.131	0.078	0.063	-0.026
	OCC -> BIC	0.272***	0.211***	0.066	0.143*	0.012
Web media communication channels	WCC -> Att	0.116***	-0.048	0.025	0.084	0.041
	WCC -> BIC	0.010	0.078	0.058	0.045	0.046
Attitude on heating equipment use	Att -> BIC	0.419***	0.577***	0.415***	0.630***	0.564***
R-squared		78.1%	74.5%	43.1%	62.7%	62.8%

Table 6 - Total effects of behavior change models tested individually in each country

This work presents the following theoretical implications. First, by developing a consumer behavior change model, this is one of the first models that joins several contexts in the decision to change to an EEHA. Other studies focused on only specific dimensions (e.g., psychological factors, house characteristics, sociodemographic characteristics). This consumer behavior change model can be a framework and sets the basis for further investigation in other types of appliances. Second, it uses the structural equation modeling technique, which is widely used in investigating consumer choice and adoption of several themes, for example, technology, but not so much in the energy sector. Third, this study uses a mixed-method approach, demonstrating the importance of both quantitative and qualitative studies, which we hope will encourage the application of this method in further investigation.

With respect to practical implications, the model developed supports decision-makers, especially regarding marketing campaigns and consumer communication. In fact, a campaign can be much more effective if people know exactly what to promote. As Wade (2016) highlighted, another strategy for energy saving is to understand the users. Thus, our findings suggest what should be promoted toward the change to EEHA, anticipating the factors that may influence consumers' intentions. For example, the presence of labelling showed to be relevant in driving people to change their heating appliances. As such, policies toward the promotion and diffusion of these labels, jointly with other campaigns, may lead to a consumer change regarding the heating appliance type, especially if these also include more information, for example, operating costs (B. Mills & Schleich, 2012).

These results dovetail with the context of energy agencies and their necessity to build campaigns and policies that meet consumers' needs and characteristics. Indeed, our work provides a complete framework in which the most important variables predicting consumers' intention to change to an EEHA are identified, as well as the most important means to communicate, showing the importance of engaging people in the topic of efficient energy and EEHA.

As shown, engagement context is the main driver of intention to change to an EEHA, suggesting the important role of affective elements in consumers' decisions, specifically in energy appliances choices. The way the topic of EEHA involves consumers, the word-of-mouth about it and the perception of how EEHA is socially accepted and perceived as a good solution is significant to the consumer intention to change, contrary to other structural factors such as house characteristics. The consumer engagement in initiatives and with energy agencies and organizations is crucial. Some strategies can also include gamification (Wee & Choong, 2019) or mobile applications (web media communication channel) as a way to increase motivation and to engage consumers in energy-efficient behaviors, notably the choice of an EEHA. Gamification consists of the development of game characteristics in a non-game context (Deterding et al., 2011).

The truth is that sometimes consumers do not know what efficient appliance to choose and what benefits they can achieve with that acquisition. Knowledge about energy use and energy saving options is positively related to the adoption of energy-efficient technologies (B. Mills & Schleich, 2012). As such, these strategies will not only increase the engagement but will also create consumers more informed about the change to an EEHA and its benefits. Consumers tend to ignore mass information and are more likely to respond to directed and targeted information (Lutzenhiser, 1993). Therefore, mobile applications and gamification strategies can provide each consumer with different types of information, depending on the consumer her/himself and the house characteristics, increasing consumers' interest.

8. CONCLUSIONS

The adoption of renewable or clean energies, as well as energy savings, has occupied more and more the interest of researchers, not only for the necessity of actually have practical implications in the mitigation of climate problems, but also to understand consumer behavior within the topic of energy. Moreover, energy policies and campaigns should integrate more insights from social science research in order to meet efficient energy goals (Edling & Danks, 2018). The adoption of EEHA is one measure that, if successfully implemented, may have several positive impacts in solving environmental problems. As such, this study contributed to a better understanding of consumer intention to change to an EEHA. This research considered six main contexts, based on a literature review and qualitative study, analysing five European countries: France, Germany, Italy, Portugal, and Spain. Based on those contexts, the drivers to behavior change were tested. Our findings show that energy efficiency and the associated label have a positive effect in both attitude and intention to change to an EEHA. Engagement and social influence also play an important role as well as co-benefits. We also confirmed the negative impact of operation and maintenance, and the relevance of organizational and web media channels. In doing so, our results had significant interest either in the study of consumer behavior either in policy or campaign makers, supporting the design of effective communication strategies.

9. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORKS

One of the limitations of this study is that it addresses only heating appliances and excludes those that cool. For future research the scope of the study could be expanded to cooling appliances. To enhance generalization, the sample for future research could also consider region differences within countries, and additional studies could also extend the comparison between countries. Authors encourage the inclusion of cultural factors in future studies. Another limitation resides in the fact that the qualitative interviews were restricted to experts in the area of energy, and did not include usual consumers, who may have different opinions. However, we considered that the variables based on literature review strongly represent the consumer perspective. Finally, although the set of variables chosen in each context of the model was validated and extended in the exploratory study, this set is not restrictive, and other variables may be used in each context.

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11. APPENDIX

11.1. APPENDIX A – DETAILS ABOUT THE QUALITATIVE STUDY INTERVIEWEES

ADENE – is a Portuguese energy agency whose mission is to develop activities of public interest in the topic of energy, with regard to the efficient consumption of water and energy. We interviewed two members responsible for the management of several projects in technical areas as energy efficiency and energy labelling.
DECO – is a Portuguese association for consumer protection whose mission is to protect the rights and interests of consumers and contribute to consumers being more informed. We interviewed a member responsible for projects in the area of innovation.
ECOS – is a European environmental organization that promotes environmental interests in Europe and internationally. We interviewed an eco-design expert.
Energies 2050 – is an international non-governmental organization working towards sustainable development and climate change. We interviewed the founder and president of the organization.
OCU – is a Spanish association for consumer protection of rights and interests. We interviewed a project officer in the area of renewable and efficient energy.
The University of Minho – is a centre of the territory, environment, and construction from the University of Minho, Portugal. We interviewed the project manager and researcher in the area of energy efficiency and sustainability, focusing in buildings.

High-level protocol questions

1. Which of the following factors do you think drive or condition consumers' intention to change to an EEHA?
2. What do you think needs to be improved in energy-efficient campaigns?
3. What information would you like to know about consumers, in this topic of changing to an EEHA?
4. From your experience, what are the triggers for consumers to change to an EEHA?
5. From your experience, what are the barriers that prevent consumers from changing to an EEHA?
6. From your experience, what is the impact of house characteristics in consumers' intention to change to an EEHA?
7. From your experience, what is the impact of engagement in consumers' intention to change to an EEHA?
8. Is there any other information that you think is relevant about consumers' intention to change to an EEHA?

Additional questions pertaining to the characteristics of the interviewees' organizations are not included.

11.2. APPENDIX B – SURVEY ITEMS

Energy Efficiency (based on Venkatesh et al. (2012))
I would be more likely to change to an EEHA (Energy Efficient Heating Appliance) if: (1 – Completely disagree; 7 – Completely agree)
EE. It will increase my house's energy efficiency

Savings (based on Michelsen and Madlener (2012))
I would be more likely to change to an EEHA (Energy Efficient Heating Appliance) if: (1 – Completely disagree; 7 – Completely agree)
Sav1. I receive a subsidy to finance the replacement
Sav2. I am aware of total energy savings over the EEHA lifetime
Sav3. I am aware of total monetary savings over the EEHA lifetime

Label (based on Sammer and Wüstenhagen (2006))
Evaluate the following sentences about energy labels. (1 – Completely disagree – 7 – Completely agree)
Lab1. The energy label is important in the decision of buying a heating appliance
Lab2. When I buy a heating appliance, I pay attention to the energy label
Lab3. I am more willing to buy a heating appliance with an efficient energy class (above C, i.e., A or B)

Operation and maintenance (based on Sopha and Klöckner (2011))
I will not purchase an EEHA (Energy Efficient Heating Appliance) because: (1 – Completely disagree – 7 – Completely agree)
OM1. I believe that the operation of an EEHA is more complicated than my current heating solution
OM2. I believe that an EEHA needs the user to perform maintenance work by himself
OM3. I believe that the maintenance of an EEHA requires too much work

Engagement (based on Vivek et al. (2012))
Evaluate the following sentences about engagement. (1 – Completely disagree – 7 – Completely agree)
EG1. I pay a lot of attention to anything about EEHA
EG2. I keep up with things related to EEHA

Social influence (based on Venkatesh et al. (2012))
Evaluate the following sentences about engagement. (1 – Completely disagree – 7 – Completely agree)
SI1. People who are important to me think that I should adopt EEHA
SI2. People who influence my behavior think that I should adopt EEHA
SI3. People whose opinions that I value prefer that I adopt EEHA

House Age (based on Michelsen and Madlener (2012))
HA. How old is your dwelling since your last renovation (in years)? If it was not renovated, answer with the years since its construction. < 1; [1, 5[; [5, 10[; [10, 15[; [15, 20[; [20, 25[; [25, 30[; >=30

House's energy class (based on Michelsen and Madlener (2012))
HEC. If known, what is the energy class of your house (based on the Energy Performance of Building Certificate)? A+; A; B; B-; C; D; E; F

Co-benefits (based on Ferreira et al. (2017))
I would be more likely to change to an EEHA (Energy Efficient Heating Appliance) if: (1 – Completely disagree; 7 – Completely agree)
CB1. Condensation, humidity and mould related problems are avoided
CB2. It will not reduce my house's useful floor area
CB3. It values the dwelling in the real-estate market (I will sell the house for a higher price if it is equipped with an EEHA)
CB4. It allows me to be independent from energy price fluctuations
CB5. It allows me to have a reduced environmental impact

Co-benefits investment (based on Ferreira et al. (2017))
Are you willing to invest an extra value for your EEHA if it allows you to: (No; Up to 100€; Between 100 and 500€; More than 500€)
CBInv1. Achieve a comfortable indoor temperature during the heating season more easily
CBInv2. Have better indoor air quality
CBInv3. Lower indoor noise level
CBInv4. Lower external noise level
CBInv5. Operate the EEHA more easily
CBInv6. Be more independent to energy prices
CBInv7. Have a more aesthetically pleasing EEHA
CBInv8. Have more useful living area
CBInv9. Value the dwelling in the real-estate market
CBInv10. Have a reduced environmental impact

Media communication channels (based on Franceschinis et al. (2017))
Evaluate the importance of the following sources to search for information about EEHA (Energy Efficient Heating Appliance). (1 – Not important; 7 – Very important)
MCC1. Newspapers
MCC2. Radio
MCC3. Television

Organization communication channels (based on Franceschinis et al. (2017))
Evaluate the importance of the following sources to search for information about EEHA (Energy Efficient Heating Appliance). (1 – Not important; 7 – Very important)
OCC1. People I know who own an EEHA
OCC2. Organizations (local associations, energy agencies)
OCC3. Installers and/or related professionals
OCC4. EEHA shop

Web media organization communication channels (based on Franceschinis et al. (2017))
Evaluate the importance of the following sources to search for information about EEHA (Energy Efficient Heating Appliance). (1 – Not important; 7 – Very important)
WCC1. Internet Websites
WCC2. Mobile Application

Attitude on heating equipment use in general (based on March et al. (2015))
Evaluate the following sentences about changing to an EEHA (Energy Efficient Heating Appliance). (1 – Completely disagree – 7 – Completely agree)
Att1. I usually track my energy consumption based on my billing (dropped)
Att2. I am willing to change my heating appliance(s)
Att3. I am planning to buy an EEHA

Behavior intention to change to an EEHA (based on Venkatesh et al. (2012))
BIC1. I intend to change to EEHA in the future
BIC2. I will try to change to EEHA in my future
BIC3. I am ready to change to EEHA

11.3. APPENDIX C – SAMPLE SIZE AND AGE AND INCOME DISTRIBUTION

	Age				Median equivalized household net income (in euros)	
Country	**Classes**	**Sample**	**Population [1]**	**Chi-squared (p-value)**	**Confidence interval [3]**	**Population [2]**
France	18 - 39	33%	33%	-0.2024	1,528 - 1,731	1,613
	≥ 40	67%	67%	-0.84		
Germany	18 - 39	32%	32%	0.14484	1,563 - 2,019	1,685
	≥ 40	68%	68%	-0.884		
Italy	18 - 39	29%	29%	0.4058	1,146 - 1,389	1,226
	≥ 40	71%	71%	-0.684		
Portugal	18 - 39	47%	30%	6.05101	804 - 1,161	716
	≥ 40	53%	70%	(<0.001)		
Spain	18 - 39	31%	31%	0.03767	1,071 - 1,346	1,073
	≥ 40	69%	69%	-0.97		

Table C.1. Age and income distribution of sample and population

Note 1: [1] Source: https://ec.europa.eu/eurostat/en/web/products-datasets/-/DEMO_PJAN (EUROSTAT: *Population on 1 January by age and sex*. The last update was 24.02.20 and extracted on 04.03.20).

Note 2: [2] Source: https://ec.europa.eu/eurostat/databrowser/bookmark/bc5e47e9-c116-4d2b-860f-293bb7a25927?lang=en (EUROSTAT: *Mean and median income by household type - EU-SILC and ECHP surveys*. The last update was 24.02.20 and extracted on 04.03.20). Median equivalized household net income considers the impact of differences in household size and composition so, the total disposable household income is "equivalized". The equivalized income attributed to each member of the household is calculated by dividing the total disposable income of the household by the equivalization factor. Equivalization factors can be determined in various ways. Eurostat applies an equivalization factor calculated according to the OECD-modified scale first proposed in 1994 - which gives a weight of 1.0 to the first person aged 14 or more, a weight of 0.5 to other persons aged 14 or more, and a weight of 0.3 to persons aged 0-13.

Note 3: [3] significance level of 0.001.

Country	**prevalence (p) [4]**	**Minimum sample size [6]**	**Sample size (n)**
France	0.19	237	363
Germany	0.12	163	179
Italy	0.22	264	357
Portugal	0.18 [5]	227	262
Spain	0.19	237	450

Table C.2. Sample size

Note 4: [4] Source: Owen and Alloh (Owen & Alloh, 2019).

Note 5: [5] Prevalence for Portugal was calculated based on the average of prevalences from the remaining four countries.

Note 6: [6] Calculated based on the sample size formula for an infinite population ($n=Z^2 p*q/d^2$), where Z is the standard normal distribution for the (1-α/2) level, d is the precision, p is the prevalence, and q=(1-p).

11.4. APPENDIX D – MEASUREMENT MODEL FOR REFLECTIVE CONSTRUCTS

	EE	Sav	Lab	OM	EG	SI	HA	HEC	Att	BIC
EE	**1.000**	0.489	0.452	-0.247	0.233	0.195	0.094	0.016	0.314	0.430
Sav1	0.311	**0.708**	0.325	-0.050	0.057	0.114	0.047	-0.102	0.186	0.188
Sav2	0.491	**0.936**	0.482	-0.168	0.139	0.172	0.065	-0.048	0.265	0.340
Sav3	0.435	**0.920**	0.441	-0.128	0.100	0.102	0.056	-0.058	0.220	0.274
Lab1	0.385	0.433	**0.887**	-0.073	0.137	0.161	-0.038	-0.025	0.263	0.276
Lab2	0.385	0.420	**0.927**	-0.136	0.225	0.222	-0.013	0.027	0.262	0.320
Lab3	0.443	0.466	**0.884**	-0.201	0.219	0.195	-0.028	0.045	0.291	0.366
OM1	-0.221	-0.118	-0.140	**0.891**	-0.187	-0.089	-0.013	-0.094	-0.131	-0.237
OM2	-0.206	-0.134	-0.126	**0.903**	-0.116	-0.034	-0.087	-0.036	-0.133	-0.242
OM3	-0.246	-0.138	-0.161	**0.946**	-0.196	-0.112	-0.090	-0.083	-0.167	-0.300
EG1	0.252	0.161	0.266	-0.164	**0.967**	0.575	-0.027	0.270	0.329	0.465
EG2	0.192	0.063	0.145	-0.192	**0.955**	0.580	-0.021	0.322	0.270	0.409
SI1	0.179	0.136	0.199	-0.085	0.594	**0.957**	0.026	0.251	0.303	0.424
SI2	0.177	0.143	0.202	-0.065	0.566	**0.969**	0.031	0.227	0.290	0.408
SI3	0.205	0.163	0.220	-0.103	0.574	**0.961**	0.022	0.239	0.304	0.435
HA	0.094	0.066	-0.029	-0.072	-0.026	0.027	**1.000**	-0.239	0.056	0.084
HEC	0.016	-0.074	0.020	-0.078	0.306	0.249	-0.239	**1.000**	0.023	0.121
Att2	0.325	0.287	0.311	-0.164	0.282	0.255	0.060	0.009	**0.894**	0.640
Att3	0.233	0.180	0.229	-0.118	0.276	0.299	0.039	0.033	**0.885**	0.569
BIC1	0.413	0.299	0.342	-0.257	0.437	0.405	0.067	0.126	0.614	**0.927**
BIC2	0.449	0.358	0.368	-0.258	0.351	0.370	0.108	0.054	0.579	**0.908**
BIC3	0.294	0.205	0.258	-0.256	0.438	0.405	0.053	0.144	0.635	**0.853**

Table 7 - Loadings and cross-loadings

	EE	Sav	Lab	OM	EG	SI	HA	HEC	Att	BIC
EE										
Sav	0.530									
Lab	0.478	0.567								
OM	0.259	0.155	0.169							
EG	0.241	0.128	0.234	0.201						
SI	0.199	0.170	0.232	0.092	0.640					
HA	0.094	0.072	0.031	0.073	0.027	0.028				
HEC	0.016	0.089	0.038	0.082	0.322	0.254	0.239			
Att	0.365	0.334	0.374	0.192	0.379	0.370	0.065	0.027		
BIC	0.459	0.368	0.405	0.320	0.506	0.478	0.090	0.129	0.845	

Table 8 - Heterotrait-Monotrait ratio (HTMT)